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TO Dr. G. A. Garrett
LOCATION K-1034

DATE December 19, 1955

ANSWERING LETTER DATE

ATTENTION

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SUBJECT Economic Recovery Limits for K-1420 Recovery Process

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The attached report, KP-933, contains pertinent information concerning the recovery and fluorination facilities in the K-1420 building. These data may be used for reporting economic recovery limits and contaminated materials accumulation rates as requested in a letter from Mr. S. R. Sapirie to Mr. L. B. Emlet, entitled "Criteria for Recovery, Storage, and Discard of Uranium Bearing Material," dated November 8, 1955.

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KP-933

ECONOMIC RECOVERY LIMITS FOR K-1420 RECOVERY PROCESS

~~#31907~~

H. G. Grisham

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UNION CARBIDE NUCLEAR COMPANY
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ECONOMIC RECOVERY LIMITS FOR K-1420 RECOVERY PROCESS

As a result of various decontamination, process, laboratory, and development activities at the K-25 plant, material is obtained which is contaminated with uranium. If the value of the contained uranium or the material with which it is associated is high enough with respect to recovery costs, the uranium is recovered from the material.

With the advent of the current plant expansion program which began in 1950, the work load for recovering uranium became excessive with the then existing facilities. This expansion program has created the need for enlarged decontamination facilities plus a more efficient and higher capacity uranium recovery system. Hence, the K-1420 building was designed and built to meet this need. A description of this recovery system with the cost of recovery at various uranium concentrations is presented below.

The approach used herein for determining the economic material recovery limits is based on a standard total contaminated material quantity throughput per day for operating costs without respect to uranium content. In considering these economic recovery limits by dollar value, it is to be emphasized that the original K-1420 building design covered discard limits of two parts per million uranium or less, which resulted in low flow systems and the provision for "always-safe" geometry or batch handling operations. Additionally, the contaminated materials being processed are high in miscellaneous impurity because of the nature of the equipment undergoing decontamination and the varying source of contaminated materials. Every type of impure material which contains uranium in the solid or liquid state and which originates anywhere in the K-25 plant is processed for recovery in the K-1420 recovery system if the worth of the contained uranium is sufficient to make such a recovery economically feasible.

Solids which contain uranium are fed into a dissolver where they are dissolved with nitric acid. The capacity of this dissolver is 750 gallons. The quantity of acid required for this dissolving process will vary, depending upon the solid being dissolved. For this report, alumina (Al_2O_3) was used as a representative solid. A quantity of 0.55 gallons of 60% nitric acid is required to dissolve one pound of alumina. Hence, a quantity of 1,200 pounds solid, using 660 gallons of nitric acid, could be dissolved on a batch basis. Each solution batch is sampled for uranium and uranium-235 content. Any undissolved solids in the resulting mixture are filtered and the filtrate is pumped to storage tanks. Impure solutions from other sources are also fed through the dissolver to these storage tanks. If the uranium concentration of the solution in the storage tanks is less than the optimum concentration (25 g. U/l.) desirable for the extraction operation, the solution is fed to pre-extraction evaporators where it is evaporated up to that concentration.

This recovery system contains two pre-evaporators whose feed rate capacity is 35 gallons per hour each with a vaporization rate of 31.5 gallons per hour each. Hence, the recovery system is limited by the capacity of these two pre-evaporators for solutions whose concentrations are below 25 grams

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uranium per liter. A quantity of 1,680 gallons may be processed through the pre-evaporators on a 24-hour per day basis. The heat load for each of these pre-evaporators is 299,000 BTU per hour, necessitating a steam requirement of approximately 15,000 pounds per 24-hour day.

Solutions whose concentrations are 25 grams uranium per liter or higher by-pass the pre-evaporators and pass directly to the extraction system as do the above-mentioned solutions after having been pre-evaporated up to that concentration. However, while the solution is still in the pre-evaporation stage and before it is fed to the extraction system, a sufficient amount of 60% nitric acid is added to insure that the nitric acid concentration in the solution after the first evaporation step is 3.5 N. After the solution has passed to the extraction system, the uranium is extracted from the impure solution with solvent (TBP). No change in uranium concentration is effected in this step. The solvent containing the purified uranium is sent to the stripping or back-out columns which remove the uranium from the solvent with water. The limiting factors in the extraction system are the continuous liquid-liquid extraction columns, whose capacity is 1,200 gallons per 24-hour day.

The resulting uranium water solution from the stripping columns is fed to other post-extraction evaporators which further concentrate the solution to 500 grams uranium per liter. These three post-evaporators have a feed rate capacity of 25 gallons per hour, or a total capacity of 1,800 gallons per 24-hour day. Hence, there is no limiting capacity in this step as related to the other stages of the recovery process. The heat load requirement for each post-evaporator is 173,000 BTU per hour, or a steam requirement of 4,280 pounds per day.

After concentrating the solution to 500 grams uranium per liter, it is fed to a drum drier where the remaining free water and excess nitric acid are removed, leaving uranyl nitrate powder (UNH). The input capacity of the drum drier is 1.25 gallons per hour with an output of 4.05 pounds UNH per hour. The system contains three drum driers with a total capacity of approximately 292 pounds UNH per 24-hour day.

This UNH is then fed to a calciner in which the powder is transformed to uranium oxide (U_3O_8 + UO_3). The capacity of a calciner is 8.1 pounds oxide per hour. The uranium oxide is then ground to a powder in a rod mill, weighed, and sampled.

The oxide is transferred to the oxide fluorination area in K-1420. A charge of approximately 8 kilograms of oxide is weighed in the charge cylinder. The material is dried in a heated screw conveyer for approximately 5 hours, and charged to a reactor where it is fluorinated to UF_6 over a period of another 5 hours. The gaseous UF_6 is cold trapped into cylinders which become available for feeding to the cascade. The cylinders are weighed and sampled. Caustic solution is used to react with any gaseous UF_6 which is not trapped out in the cylinders. The caustic solution is measured, sampled, and transferred back to the recovery system. Fluorination costs at K-1420 were calculated to be $25 per kilogram uranium plus $1.83 per kilogram uranium for depreciation of equipment. Material at an assay less than 1% can be more economically fluorinated at K-1131. The cost there was calculated to be $1.40 per kilogram uranium including depreciation.

The recovery system in K-1420 is made up of three separate lines or systems: (1) mixer-settler system, (2) "A" continuous recovery system, and (3) "B" continuous recovery system. However, the mixer-settler system is used exclusively for the K-1420 decontamination process. Hence, for this report, only the two remaining systems are considered with respect to capacities and costs.

The economic recovery limits for contaminated solids are shown in figure 1, and for contaminated solutions in figure 2. It will be noted that a discontinuity exists in each figure at the 1% assay level. The reason for this is that the assumption has been made that oxide produced from the recovery system having an assay less than 1% may be more economically fluorinated in the feed manufacturing plant (building K-1131), while that above 1% must be fluorinated to UF_6 in the fluorination area of the K-1420 building. Processing costs for the various phases of the recovery operation are included in tabular form as follows: Table 1 represents the dissolving costs for solids at various uranium concentrations; table 2 shows the recovery costs from solutions to oxide also at various uranium concentrations; and table 3 gives the fluorination costs when below 1% (K-1131 building) and above 1% (K-1420 building). Salvage quantities presently on hand awaiting recovery, together with estimated future accumulation rates, are shown in table 4. Also in this table are included the economically recoverable quantities on hand and in future generation as determined by the criteria of figures 1 and 2; the number of required containers and estimated cost of storage are shown for those quantities which are not economically recoverable.

The following standard costs on a daily basis were calculated as shown below:

Labor: The man-hours of labor per 24-hour day were estimated to be 12 hours per batch for dissolving solids. Two batches of 750 gallons can be run per day. The labor for all other processes in recovery from solutions to oxide was assigned at 92 man-hours, and 24 man-hours for fluorination from oxide to UF_6.

Overhead: Overhead was calculated at the present normal plant figure of 98% of direct labor.

Depreciation: Depreciation for the recovery system was figured on a capital investment of $1,850,000 to be amortized on a 20-year basis. A capital investment of $600,000 to be amortized over the same period of time was used for the fluorination system.

Maintenance: Maintenance (labor and materials) was calculated in accordance with recent experience and in line with budget estimates.

Steam Cost: The steam requirement was calculated by using the heat load of the various evaporators, driers, calciners, and dissolvers as a basis.

The steam requirement was then applied to an average steam cost of $0.64 per 1,000 pounds to determine the total steam cost on a 24-hour per day basis.

Acid Cost: Nitric acid is used in two instances in the recovery system as follows: (1) dissolving solids and (2) maintaining normality of solution at 3.5 N before entering extraction system. The quantity of acid needed for dissolving solids was calculated at 0.55 gallons per pound solid. The quantity of acid required in maintaining normality at 3.5 N was that quantity which was added to solution at initial concentration before evaporation which permitted solution after evaporation to have a nitric acid concentration of 3.5 N. An average price of $0.327 per gallon was applied to the total daily nitric acid usage.

Sampling Cost: A sample was taken for each batch of 750 gallons of initial solution at a calculated cost of $18.50 per sample. One sample was taken for each container of oxide (9,500 grams) at a cost of $23.50 per sample. One sample was taken for each cylinder of UF_6 (15 kilograms) at a cost of $20.50 per sample. Also included in sampling costs is the daily cost of maintaining a Process Control Sampling Laboratory in K-1420 which was calculated to be $128.10. These sampling costs were combined and expressed on a per kilogram basis.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Mr. R. J. Clouse and Mr. J. Dykstra, Jr., for the comprehensive help in compiling the operating data in the K-1420 recovery process toward the preparation of this report and to Mr. J. W. Arendt for the table of salvage quantities.

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TABLE 1

SOLIDS TO SOLUTION

Initial Concentration, Grams U/Gram	Dissolving Costs - $/Kg. U				Solution Concentration, PPM
	Direct Labor	Overhead	HNO_3	Total	
0.000014	3,842.52	3,765.09	28,322.80	35,930.41	3
0.000023	2,338.66	2,291.89	17,238.02	21,868.57	5
0.000046	1,169.33	1,145.94	8,619.01	10,934.28	10
0.000230	233.88	229.20	1,723.94	2,187.02	50
0.000459	117.20	114.86	863.83	1,095.89	100
0.001148	46.86	45.92	345.38	438.16	250
0.00230	23.39	22.92	172.39	218.70	500
0.00459	11.72	11.49	86.38	109.59	1,000
0.00918	5.86	5.74	43.19	54.79	2,000
0.01377	3.84	3.76	28.79	36.39	3,000
0.0230	2.34	2.29	17.25	21.88	5,000
0.0459	1.17	1.15	8.64	10.96	10,000
0.0688	0.78	0.76	5.76	7.30	15,000
0.1148	0.47	0.46	3.45	4.38	25,000

Note: The capacity of the dissolver is 750 gallons per batch or approximately 1,200 pounds solids. Two batches can be processed per 24-hour day. The capacity of the dissolver is approximately 72,000 pounds of solids per month at assays below 2%. Higher assays are limited by critical hazards requirements.

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TABLE 2

SOLUTIONS TO OXIDE

Initial Concentration		Recovery Cost (Solution to Oxide) - $/Kg. U							
PPM	Grams U/Gal.	Direct Labor	Overhead	HNO_3	Sampling	Maintenance	Depreciation	Misc.*	Total
3	0.01136	12,208.33	11,964.07	0.98	8,840.10	8,846.86	13,198.97	2,223.43	57,282.74
5	0.01893	7,325.00	7,178.44	0.94	5,304.06	5,308.12	7,919.38	1,334.06	34,370.00
10	0.03785	3,662.50	3,589.22	0.93	2,652.03	2,654.06	3,959.69	667.03	17,185.46
50	0.1893	737.11	722.36	0.91	536.26	534.15	796.92	134.40	3,462.11
100	0.3785	369.13	361.75	0.93	269.78	267.50	399.09	67.31	1,735.49
250	0.9462	147.89	144.93	0.95	109.56	107.17	159.89	27.00	697.39
500	1.8925	75.01	73.51	0.95	56.83	54.36	81.09	13.72	355.47
1,000	3.785	37.22	36.47	0.86	29.45	26.97	40.24	6.90	178.11
2,000	7.570	18.83	18.46	0.95	16.11	13.65	20.36	3.53	91.89
3,000	11.355	12.69	12.43	0.94	11.73	9.19	13.72	2.40	63.10
5,000	18.925	7.79	7.63	0.98	8.12	5.64	8.42	1.50	40.08
10,000	37.850	4.13	4.05	1.04	5.39	2.99	4.46	0.83	22.89
15,000	56.775	2.90	2.85	1.05	4.52	2.10	3.14	0.61	17.17
25,000	94.625	2.82	2.77	1.27	4.32	2.05	3.05	0.48	16.76

*Miscellaneous costs include steam, water, electricity, etc.

Note: The K-1420 recovery system is limited by the pre-evaporation facilities for all solutions with a concentration less than 8.3 grams uranium per liter. The capacity of the pre-evaporators is 1,680 gallons of feed solution per day. The extraction system limits solutions over 25 grams uranium per liter to 1,200 gallons per day. There are no assay limitations on this part of the recovery system. The monthly capacity of the evaporator system is approximately 50,000 gallons.

TABLE 3

FLUORINATION COST

Uranium-235 Assay	Fluorination Cost, $/Kg. U	Depreciation, $/Kg. U	Total, $/Kg. U
Below 1% (K-1131)	1.15	0.25	1.40
Above 1% (K-1420)	25.00	1.83	26.83

Note: The capacity of the K-1420 fluorination system for material above 1% assay is 45 kilograms per 24-hour day.

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TABLE 4

SALVAGE QUANTITIES

Assay	Present Inventory		Future Generation		Storage of Unrecoverable Quantities			
					Present Inventory		Future Generation	
	Total Kg. U	To Be Recovered, Kg. U	Total Kg. U/Yr.	To Be Recovered, Kg. U/Yr.	Number of Containers	Dollars per Year	Number of Containers per Year	Dollars per Year
< .4	1,025.197	1,016.166	1,000	991.0	4	21.60	8	51.20
.4-1	18,632.049	18,349.221	10,000	9,850.0	579	3,126.60	311	1,990.40
1-2	3,733.978	3,643.160	800	780.0	523	2,824.20	115	736.00
2-10	1,155.825	1,141.812	500	494.0	560	3,024.00	242	1,548.80
10-30	225.225	224.319	200	199.0	112	604.80	100	640.00
30-75	15.072	15.054	25	24.9	23	124.20	38	243.20
75 and above	4.391	4.371	32	31.8	27	145.80	50	320.00
Total	24,791.737	24,394.103	12,557	12,370.7	1,828	9,871.20	864	5,529.60

Representative types of contaminated materials:

Alumina
Incinerator Ash
Hydrocarbon Oil
Fluorination Ash
Feed Manufacture Scrap (Impure Intermediates)
Laboratory Waste
Miscellaneous Water or Acid Solutions
Filter Cake
Decontamination Solutions

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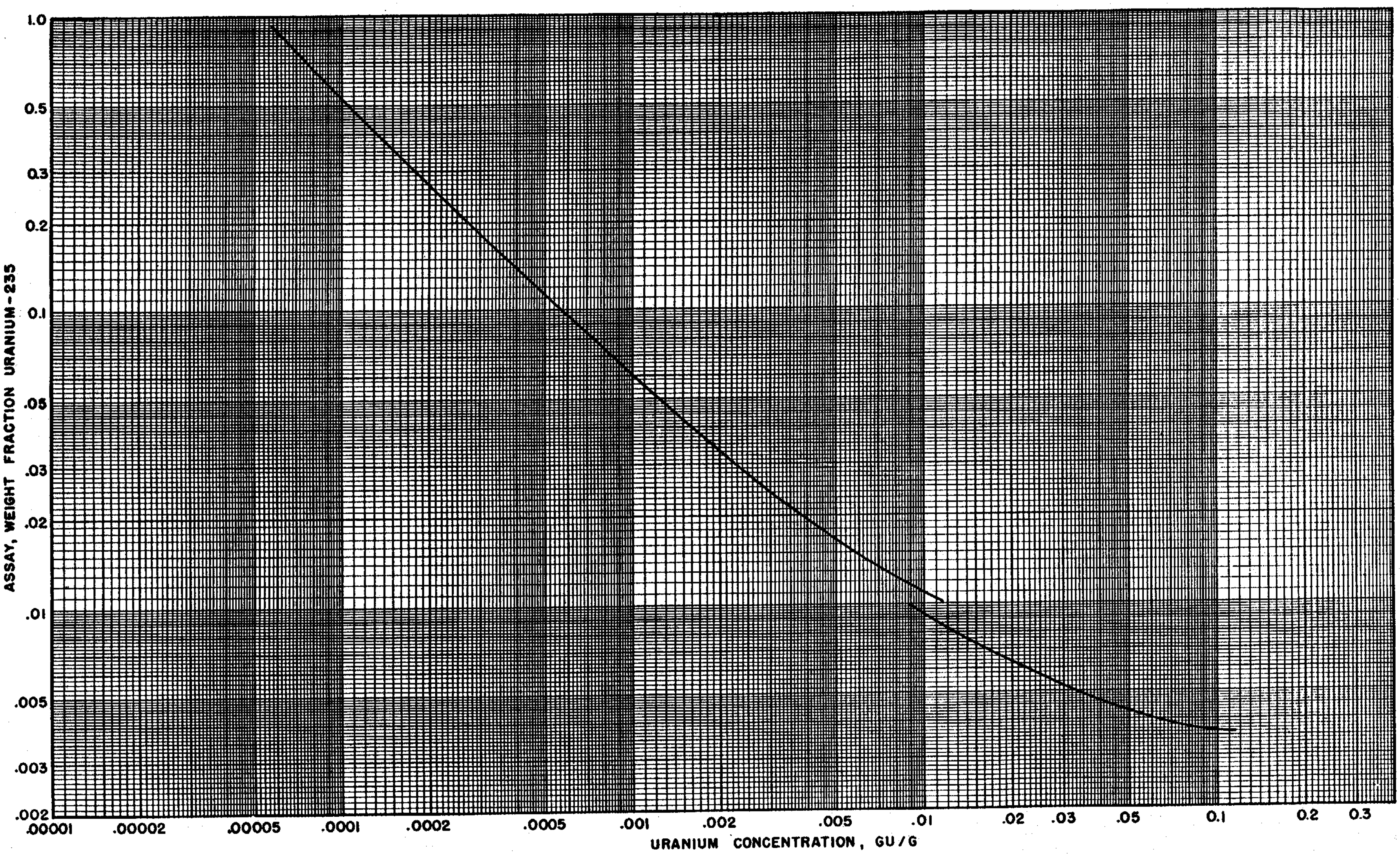

ECONOMIC URANIUM RECOVERY LIMITS-ASSAYS FOR SOLIDS

FIGURE 1

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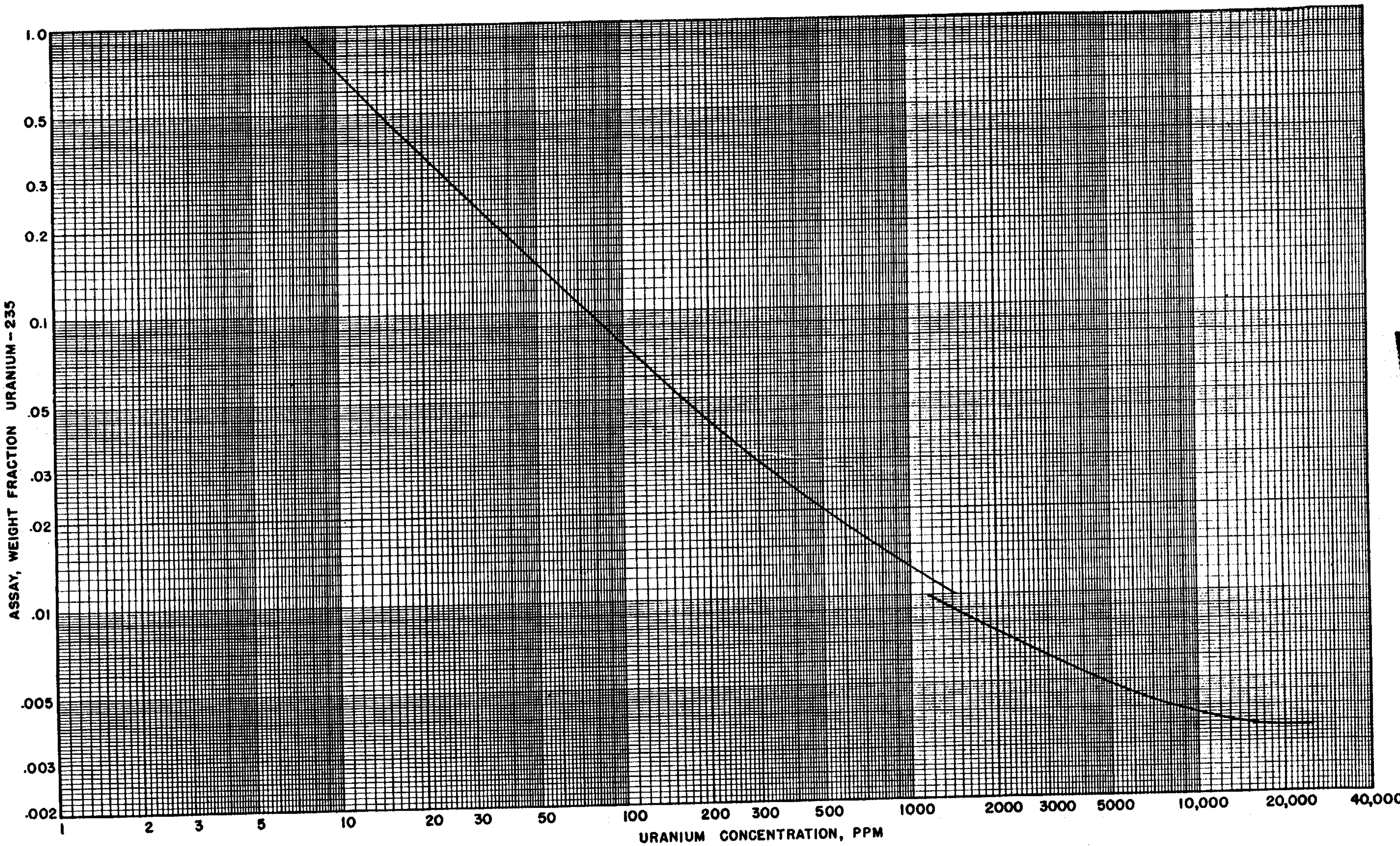

ECONOMIC URANIUM RECOVERY LIMITS-ASSAYS FOR SOLUTIONS

FIGURE 2

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